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PATENT

Atty. Docket No. ACX-103CN5  
(180/12)

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

APPLICANT(S): Lazarus et al.

SERIAL NUMBER: Not yet assigned      GROUP NUMBER: Not yet assigned

FILING DATE: Herewith      EXAMINER: Not yet assigned

TITLE: Packaged Strain Actuator

Assistant Commissioner for Patents  
Washington, D.C. 20231

**PRELIMINARY AMENDMENT**

Sir:

Before examining the above-identified application, kindly amend the application as follows:

**IN THE SPECIFICATION:**

Immediately under the title, please add the following section:

**--Related Applications**

This application is a continuation of Application No. 08/943,646, filed October 3, 1997, which is a continuation of Application No. 08/188,145, filed January 27, 1994.--

**IN THE CLAIMS:**

Please cancel claims 1-20 without prejudice, amend claims 21, 23, 25, 26, and 30, and add new claims 32-57 as follows:

21. (Amended) A method of forming an actuator, such method comprising the steps of forming a flex circuit having conductive traces arranged in a pattern

bonding an electro-active [ceramic sheet] element to the flex circuit such that the electro-active element is in contact with at least some of said conductive traces, and

assembling the flex circuit and the electro-active [ceramic sheet] element together so as to constitute a card such that the [sheet] electro-active element has a non-shear coupling over a region to an outer face of the card and is electrically coupled over said region to an electrode of said flex circuit.

23. (Amended) A method of forming an electro-active device, such method comprising the [step] steps of:

preparing first and second flex circuits with first and second electrodes and a recess therebetween, and

bonding at least one electro-active element in the recess in mechanical and electrical contact with said flex circuits over its surface area to form a unitary electro-active structure.

25. (Amended) The method of claim 21, wherein the step of bonding includes bonding plural pairs of electro-active [ceramic sheets] elements in the card.

26. (Amended) The method of claim 21, wherein said flex circuit is pliable in a region away from said electro-active [ceramic sheet] element.

30. (Amended) The method of claim 21, wherein the step of bonding hardens the flex circuit and bonded electro-active [ceramic sheet] element into a card.

32. The actuator device of claim 56, wherein said electro-active ceramic element is bonded to said polymer insulator with a material selected from the group consisting of a heat-curable epoxy, a pressure-curable epoxy, and a low temperature adhesive.

33. The actuator device of claim 56, wherein said polymer insulator comprises a material selected from the group consisting of a polyamide, a polyimide, and a polyester.

34. The actuator device of claim 56, further comprising at least one spacer coplanar with said electro-active ceramic element, wherein the at least one spacer contacts the polymer insulator.

35. The actuator device of claim 34, wherein said spacer comprises a frame.

36. The actuator device of claim 56, wherein said conductor comprises an electrode.

37. The actuator device of claim 56, wherein said electro-active ceramic element is bonded to said polymer insulator with a material comprising a heat-curable epoxy, thereby providing strength to said actuator device.

38. The actuator device of claim 56, wherein said electro-active element comprises a first electro-active element and a second electro-active element, each of said first and second electro-active elements having at least one metal-coated surface.

39. The actuator device of claim 38, wherein said metal-coated surface of said first electro-active element is in direct electrical contact with said metal-coated surface of said second electro-active element.

40. The actuator device of claim 56, wherein said electro-active element comprises a first electro-active element having a metal-coated surface, and a second electro-active element, and wherein said second electro-active element is in direct electrical contact with said metal-coated surface of said first electro-active element.

41. The actuator device of claim 40 further comprising at least one spacer substantially coplanar to the electro-active ceramic element, wherein the spacer contacts the polymer insulator.

42. The actuator device of claim 56, said device further comprising an enclosing layer encasing said electro-active ceramic element and said flex circuit, and wherein said actuator device forms a card.

43. The actuator device of claim 21, further having a metal layer comprising copper.

44. The actuator device of claim 56, wherein said actuator device has a curved shape.

45. The actuator device of claim 37, wherein said heat-curable epoxy forms a bonding layer defining a plurality of voids.

46. The actuator device of claim 45, wherein said second conductor is in direct electrical contact with said electro-active element through said voids.

47. The actuator device of claim 56, wherein said actuator device is configured as a stack, a flexure, a shell, a plate, or a bender.

48. An actuator device comprising:

an electro-active ceramic element including a first conductor;

a second conductor, and

a polymer insulator,

wherein at least said second conductor is in direct electrical contact with said first conductor of said electro-active ceramic element, and

wherein said electro-active ceramic element and said polymer insulator are bonded together such that in-plane strain in said electro-active element is shear coupled between said electro-active element and said insulator,

further comprising at least one circuit element in electrical communication with the electro-active ceramic element.

49. The actuator device of claim 43, said electro-active element comprising a first electro-active element and a second electro-active element, and said metal layer having a first surface and a second surface,

wherein said first surface of said metal layer is in direct electrical contact with said first electro-active element, and

wherein said second surface of said metal layer is in direct electrical contact with said second electro-active element.

50. The actuator device of claim 56, wherein said second conductor is positioned between said electro-active ceramic element and said polymer insulator.

51. The actuator device of claim 56, wherein said second conductor is positioned such that a portion of said second conductor is in physical contact with said electro-active element.

52. The actuator device of claim 56 further comprising an electrical connector in direct electrical contact with said second conductor.

53. The actuator device of claim 56 wherein said second conductor is in direct electrical contact with said electro-active element at a plurality of points.

54. The actuator device of claim 56, wherein said actuator device is shear-coupled to an object.

55. A method for damping vibration of an object, said method comprising the steps of:

(a) bonding the actuator device of claim 56 to a surface of the object such that in-plane strain of the electro-active ceramic element mechanically acts on the object through said polymer insulator when an electrical signal is applied to said second conductor; and

(b) applying an electrical signal to said second conductor.

56. An actuator device comprising:

an electro-active ceramic element including a first conductor; and

a flex circuit comprising a polymer insulator and a second conductor,

wherein said electro-active ceramic element is bonded to said flex circuit such that in-plane strain in said electro-active ceramic element is shear coupled between said electro-active ceramic element and said flex circuit, and

wherein said second conductor is in direct electrical contact with said first conductor of said electro-active ceramic element.

57. An actuator device comprising:

an electro-active ceramic element;

a flex circuit comprising a polymer insulator, a first electrode and a second electrode;

and

a bonding layer adhering said electro-active ceramic element to said flex circuit such that in-plane strain in said electro-active ceramic element is shear coupled between said electro-active element and said flex circuit,

wherein each of said first and second electrodes is configured as a comb having a plurality of teeth, said first and second electrodes being interdigitated,

wherein said first and second electrodes are in direct electrical contact with said electro-active ceramic element, and

wherein said electro-active element having a first surface and a second surface, said first and second electrodes being in direct electrical contact with said first surface of said electro-active ceramic element, and

said flex circuit further comprising a third electrode and a forth electrode,

wherein both of said third and forth electrodes are configured as a comb having a plurality of teeth, said third and forth electrodes being interdigitated,

wherein said third and forth electrodes are in direct electrical contact with said second surface of said electro-active ceramic element, and

wherein said third and forth electrode are connected to said first and second electrode through equipotential lines extending through said electro-active ceramic element.

### **REMARKS**

Following entry of the amendments, claims 21-57 are pending in this application.

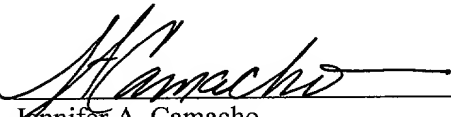
Claims 1-20 are canceled without prejudice, and without any intention to abandon the subject matter of these claims as filed or later amended, but with the intention that claims of the same, greater, or lesser scope may be pursued in a continuing application.

New claims 32-57 recite embodiments of an actuator device, and methods for making and using an actuator device. Support for new claims 32-57 is found in the specification as filed. Enclosed is a copy of the amended claim in mark-up format, as well as a clean set of the pending claims as amended. No new matter has been introduced.

Applicants submit that the claims are allowable. If the Examiner believes that a telephone conversation would be helpful, the Examiner is invited to telephone the undersigned attorney.

Respectfully submitted,

4/18/01  
Date

  
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479JAC180/12.2073285

## CLEAN COPY OF ALL PENDING CLAIMS

1 - 20 Canceled

21. A method of forming an actuator, such method comprising the steps of
- forming a flex circuit having conductive traces arranged in a pattern
- bonding an electro-active element to the flex circuit such that the electro-active element is in contact with at least some of said conductive traces, and
- assembling the flex circuit and the electro-active element together so as to constitute a card such that the electro-active element has a non-shear coupling over a region to an outer face of the card and is electrically coupled over said region to an electrode of said flex circuit.
22. The method of claim 21, wherein the step of assembling includes assembling circuit elements in said card.
23. A method of forming an electro-active device, such method comprising the steps of:
- preparing first and second flex circuits with first and second electrodes and a recess therebetween, and
- bonding at least one electro-active element in the recess in mechanical and electrical contact with said flex circuits over its surface area to form a unitary electro-active structure.
24. The method of claim 23, further comprising the step of attaching circuit elements on said first and second flex circuits.
25. The method of claim 21, wherein the step of bonding includes bonding plural pairs of electro-active elements in the card.
26. The method of claim 21, wherein said flex circuit is pliable in a region away from said electro-active element.
27. The method of claim 23, wherein the step of preparing includes preparing at least three flex circuits.
28. The method of claim 21, further comprising the step of bonding a surface of said flex circuit to an object whereby the device mechanically acts on said object through the flex circuit when signals are applied to the electrode.
29. The method of claim 21, wherein the step of bonding is performed with a patterned layer of bonding material co-planar with at least some of said conductive traces.
30. The method of claim 21, wherein the step of bonding hardens the flex circuit and bonded electro-active element into a card.
31. The method of claim 21, wherein the actuator is a simple mechanical device selected from among pushers, vanes, flaps, levers, benders, bellows and combinations thereof.

32. The actuator device of claim 56, wherein said electro-active ceramic element is bonded to said polymer insulator with a material selected from the group consisting of a heat-curable epoxy, a pressure-curable epoxy, and a low temperature adhesive.
33. The actuator device of claim 56, wherein said polymer insulator comprises a material selected from the group consisting of a polyamide, a polyimide, and a polyester.
34. The actuator device of claim 56, further comprising at least one spacer coplanar with said electro-active ceramic element, wherein the at least one spacer contacts the polymer insulator.
35. The actuator device of claim 34, wherein said spacer comprises a frame.
36. The actuator device of claim 56, wherein said conductor comprises an electrode.
37. The actuator device of claim 56, wherein said electro-active ceramic element is bonded to said polymer insulator with a material comprising a heat-curable epoxy, thereby providing strength to said actuator device.
38. The actuator device of claim 56, wherein said electro-active element comprises a first electro-active element and a second electro-active element, each of said first and second electro-active elements having at least one metal-coated surface.
39. The actuator device of claim 38, wherein said metal-coated surface of said first electro-active element is in direct electrical contact with said metal-coated surface of said second electro-active element.
40. The actuator device of claim 56, wherein said electro-active element comprises a first electro-active element having a metal-coated surface, and a second electro-active element, and wherein said second electro-active element is in direct electrical contact with said metal-coated surface of said first electro-active element.
41. The actuator device of claim 40 further comprising at least one spacer substantially coplanar to the electro-active ceramic element, wherein the spacer contacts the polymer insulator.
42. The actuator device of claim 56, said device further comprising an enclosing layer encasing said electro-active ceramic element and said flex circuit, and wherein said actuator device forms a card.
43. The actuator device of claim 21, further having a metal layer comprising copper
44. The actuator device of claim 56, wherein said actuator device has a curved shape.
45. The actuator device of claim 37, wherein said heat-curable epoxy forms a bonding layer defining a plurality of voids.
46. The actuator device of claim 45, wherein said second conductor is in direct electrical contact with said electro-active element through said voids.
47. The actuator device of claim 56, wherein said actuator device is configured as a stack, a flexure, a shell, a plate, or a bender.
48. An actuator device comprising:  
an electro-active ceramic element including a first conductor;



a second conductor, and

a polymer insulator,

wherein at least said second conductor is in direct electrical contact with said first conductor of said electro-active ceramic element, and

wherein said electro-active ceramic element and said polymer insulator are bonded together such that in-plane strain in said electro-active element is shear coupled between said electro-active element and said insulator,

further comprising at least one circuit element in electrical communication with the electro-active ceramic element.

49. The actuator device of claim 43, said electro-active element comprising a first electro-active element and a second electro-active element, and said metal layer having a first surface and a second surface,

wherein said first surface of said metal layer is in direct electrical contact with said first electro-active element, and

wherein said second surface of said metal layer is in direct electrical contact with said second electro-active element.

50. The actuator device of claim 56, wherein said second conductor is positioned between said electro-active ceramic element and said polymer insulator.

51. The actuator device of claim 56, wherein said second conductor is positioned such that a portion of said second conductor is in physical contact with said electro-active element.

52. The actuator device of claim 56 further comprising an electrical connector in direct electrical contact with said second conductor.

53. The actuator device of claim 56 wherein said second conductor is in direct electrical contact with said electro-active element at a plurality of points.

54. The actuator device of claim 56, wherein said actuator device is shear-coupled to an object.

55. A method for damping vibration of an object, said method comprising the steps of:

(a) bonding the actuator device of claim 56 to a surface of the object such that in-plane strain of the electro-active ceramic element mechanically acts on the object through said polymer insulator when an electrical signal is applied to said second conductor; and

(b) applying an electrical signal to said second conductor.

56. An actuator device comprising:

an electro-active ceramic element including a first conductor; and

a flex circuit comprising a polymer insulator and a second conductor,

wherein said electro-active ceramic element is bonded to said flex circuit such that in-plane strain in said electro-active ceramic element is shear coupled between said electro-active ceramic element and said flex circuit, and

wherein said second conductor is in direct electrical contact with said first conductor of said electro-active ceramic element.

57. An actuator device comprising:

an electro-active ceramic element;

a flex circuit comprising a polymer insulator, a first electrode and a second electrode;

and

a bonding layer adhering said electro-active ceramic element to said flex circuit such that in-plane strain in said electro-active ceramic element is shear coupled between said electro-active element and said flex circuit,

wherein each of said first and second electrodes is configured as a comb having a plurality of teeth, said first and second electrodes being interdigitated,

wherein said first and second electrodes are in direct electrical contact with said electro-active ceramic element, and

wherein said electro-active element having a first surface and a second surface, said first and second electrodes being in direct electrical contact with said first surface of said electro-active ceramic element, and

said flex circuit further comprising a third electrode and a forth electrode,

wherein both of said third and forth electrodes are configured as a comb having a plurality of teeth, said third and forth electrodes being interdigitated,

wherein said third and forth electrodes are in direct electrical contact with said second surface of said electro-active ceramic element, and

wherein said third and forth electrode are connected to said first and second electrode through equipotential lines extending through said electro-active ceramic element.--

## MARKED-UP COPY OF AMENDMENTS TO THE CLAIMS

21. (Amended) A method of forming an actuator, such method comprising the steps of
- forming a flex circuit having conductive traces arranged in a pattern
- bonding an electro-active [ceramic sheet] element to the flex circuit such that the electro-active element is in contact with at least some of said conductive traces, and
- assembling the flex circuit and the electro-active [ceramic sheet] element together so as to constitute a card such that the [sheet] electro-active element has a non-shear coupling over a region to an outer face of the card and is electrically coupled over said region to an electrode of said flex circuit.
23. (Amended) A method of forming an electro-active device, such method comprising the [step] steps of:
- preparing first and second flex circuits with first and second electrodes and a recess therebetween, and
- bonding at least one electro-active element in the recess in mechanical and electrical contact with said flex circuits over its surface area to form a unitary electro-active structure.
25. (Amended) The method of claim 21, wherein the step of bonding includes bonding plural pairs of electro-active [ceramic sheets] elements in the card.
26. (Amended) The method of claim 21, wherein said flex circuit is pliable in a region away from said electro-active [ceramic sheet] element.
30. (Amended) The method of claim 21, wherein the step of bonding hardens the flex circuit and bonded electro-active [ceramic sheet] element into a card.
- 32. The actuator device of claim 56, wherein said electro-active ceramic element is bonded to said polymer insulator with a material selected from the group consisting of a heat-curable epoxy, a pressure-curable epoxy, and a low temperature adhesive.
33. The actuator device of claim 56, wherein said polymer insulator comprises a material selected from the group consisting of a polyamide, a polyimide, and a polyester.
34. The actuator device of claim 56, further comprising at least one spacer coplanar with said electro-active ceramic element, wherein the at least one spacer contacts the polymer insulator.
35. The actuator device of claim 34, wherein said spacer comprises a frame.
36. The actuator device of claim 56, wherein said conductor comprises an electrode.
37. The actuator device of claim 56, wherein said electro-active ceramic element is bonded to said polymer insulator with a material comprising a heat-curable epoxy, thereby providing strength to said actuator device.

38. The actuator device of claim 56, wherein said electro-active element comprises a first electro-active element and a second electro-active element, each of said first and second electro-active elements having at least one metal-coated surface.
39. The actuator device of claim 38, wherein said metal-coated surface of said first electro-active element is in direct electrical contact with said metal-coated surface of said second electro-active element.
40. The actuator device of claim 56, wherein said electro-active element comprises a first electro-active element having a metal-coated surface, and a second electro-active element, and wherein said second electro-active element is in direct electrical contact with said metal-coated surface of said first electro-active element.
41. The actuator device of claim 40 further comprising at least one spacer substantially coplanar to the electro-active ceramic element, wherein the spacer contacts the polymer insulator.
42. The actuator device of claim 56, said device further comprising an enclosing layer encasing said electro-active ceramic element and said flex circuit, and wherein said actuator device forms a card.
43. The actuator device of claim 21, further having a metal layer comprising copper
44. The actuator device of claim 56, wherein said actuator device has a curved shape.
45. The actuator device of claim 37, wherein said heat-curable epoxy forms a bonding layer defining a plurality of voids.
46. The actuator device of claim 45, wherein said second conductor is in direct electrical contact with said electro-active element through said voids.
47. The actuator device of claim 56, wherein said actuator device is configured as a stack, a flexure, a shell, a plate, or a bender.
48. An actuator device comprising:
- an electro-active ceramic element including a first conductor;
  - a second conductor, and
  - a polymer insulator,
- wherein at least said second conductor is in direct electrical contact with said first conductor of said electro-active ceramic element, and
- wherein said electro-active ceramic element and said polymer insulator are bonded together such that in-plane strain in said electro-active element is shear coupled between said electro-active element and said insulator,
- further comprising at least one circuit element in electrical communication with the electro-active ceramic element.
49. The actuator device of claim 43, said electro-active element comprising a first electro-active element and a second electro-active element, and said metal layer having a first surface and a second surface,

wherein said first surface of said metal layer is in direct electrical contact with said first electro-active element, and

wherein said second surface of said metal layer is in direct electrical contact with said second electro-active element.

50. The actuator device of claim 56, wherein said second conductor is positioned between said electro-active ceramic element and said polymer insulator.

51. The actuator device of claim 56, wherein said second conductor is positioned such that a portion of said second conductor is in physical contact with said electro-active element.

52. The actuator device of claim 56 further comprising an electrical connector in direct electrical contact with said second conductor.

53. The actuator device of claim 56 wherein said second conductor is in direct electrical contact with said electro-active element at a plurality of points.

54. The actuator device of claim 56, wherein said actuator device is shear-coupled to an object.

55. A method for damping vibration of an object, said method comprising the steps of:

(a) bonding the actuator device of claim 56 to a surface of the object such that in-plane strain of the electro-active ceramic element mechanically acts on the object through said polymer insulator when an electrical signal is applied to said second conductor; and

(b) applying an electrical signal to said second conductor.

56. An actuator device comprising:

an electro-active ceramic element including a first conductor; and

a flex circuit comprising a polymer insulator and a second conductor,

wherein said electro-active ceramic element is bonded to said flex circuit such that in-plane strain in said electro-active ceramic element is shear coupled between said electro-active ceramic element and said flex circuit, and

wherein said second conductor is in direct electrical contact with said first conductor of said electro-active ceramic element.

57. An actuator device comprising:

an electro-active ceramic element;

a flex circuit comprising a polymer insulator, a first electrode and a second electrode;

and

a bonding layer adhering said electro-active ceramic element to said flex circuit such that in-plane strain in said electro-active ceramic element is shear coupled between said electro-active element and said flex circuit,

wherein each of said first and second electrodes is configured as a comb having a plurality of teeth, said first and second electrodes being interdigitated,

wherein said first and second electrodes are in direct electrical contact with said electro-active ceramic element, and

wherein said electro-active element having a first surface and a second surface, said first and second electrodes being in direct electrical contact with said first surface of said electro-active ceramic element, and

said flex circuit further comprising a third electrode and a forth electrode,

wherein both of said third and forth electrodes are configured as a comb having a plurality of teeth, said third and forth electrodes being interdigitated,

wherein said third and forth electrodes are in direct electrical contact with said second surface of said electro-active ceramic element, and

wherein said third and forth electrode are connected to said first and second electrode through equipotential lines extending through said electro-active ceramic element.

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